Recent Results on χ_{cJ} Decays at BESIII

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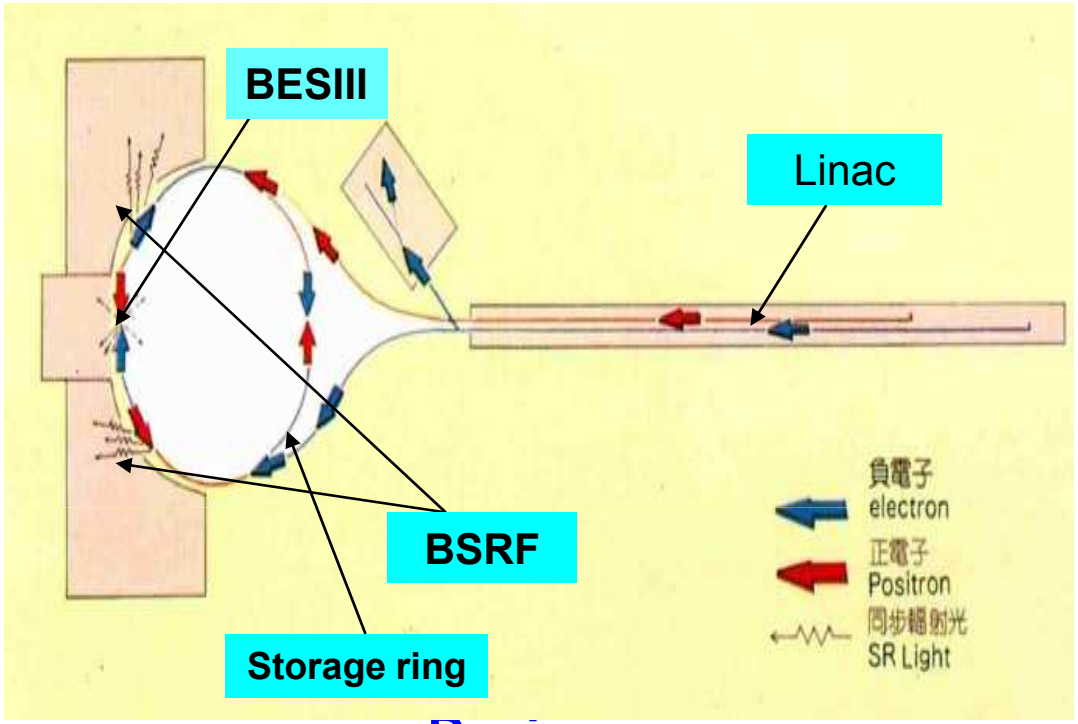
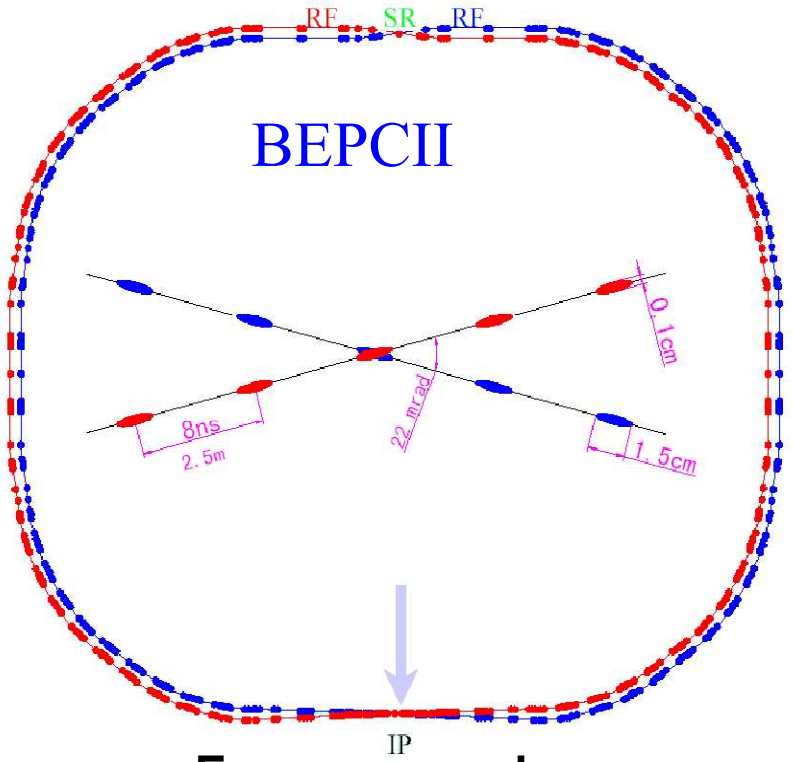
Outline

- Introduction
- Studies of $\chi_{cJ} \to \pi^0\pi^0/\eta\eta$
- Preliminary Results of $\chi_{cJ} \to \phi\phi/\omega\omega/\phi\omega$
- Preliminary Results of $\chi_{cJ} \to \gamma\phi/\gamma\rho/\gamma\omega$
- Summary

Beijing Electron Positron Collider





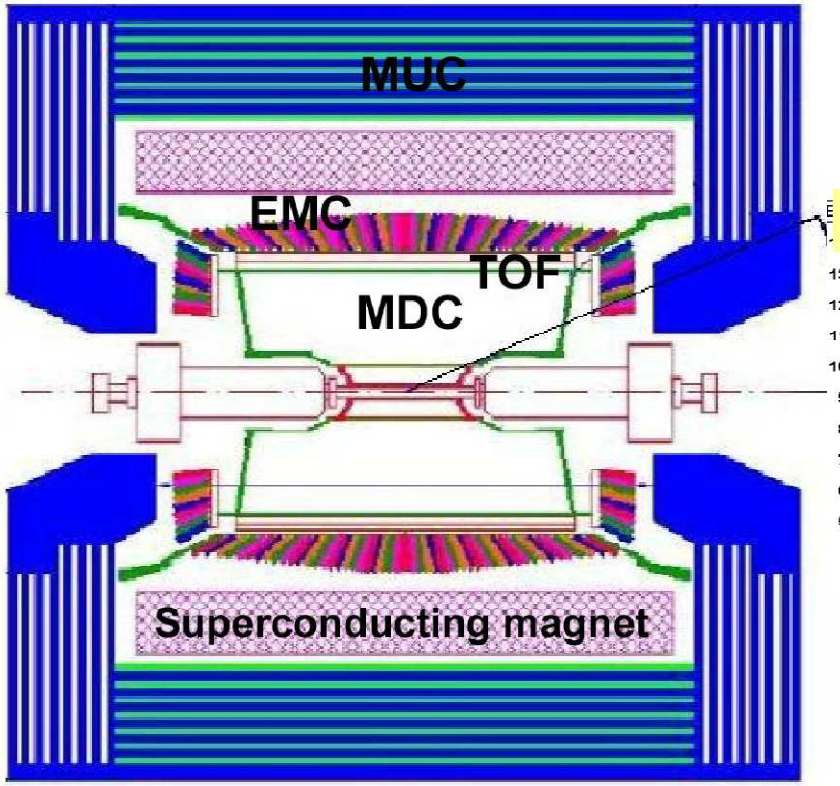
Designs:

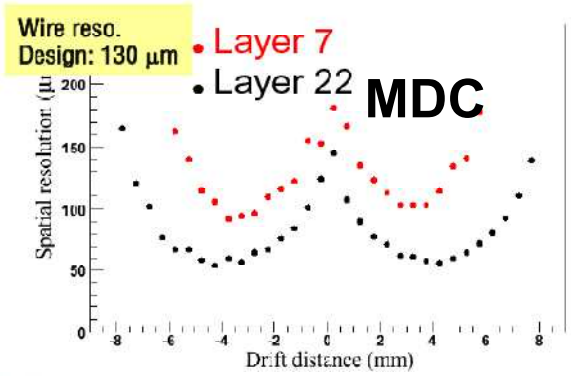
- **Beam energy:**
  - **1.0-2.3 GeV**
- **Luminosity:**
  - **1×10^{33} $cm^{-2}s^{-1}$**
- **Optimum energy:**
  - **1.89 GeV**
- **Energy spread:**
  - **5.16×10^{-4}**
- **No. of bunches:**
  - **93**
- **Bunch length:**
  - **1.5 cm**
- **Total current:**
  - **0.91 A**

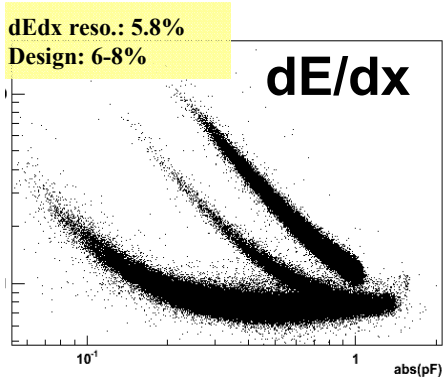
Beijing Spectrometer BESIII

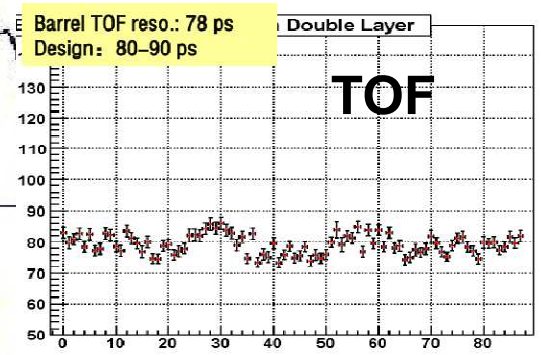
NIM paper published:

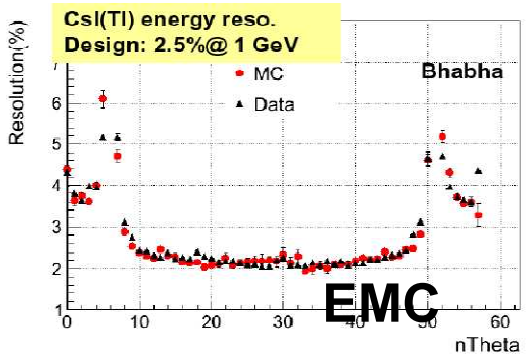
arXiv:0911.4960







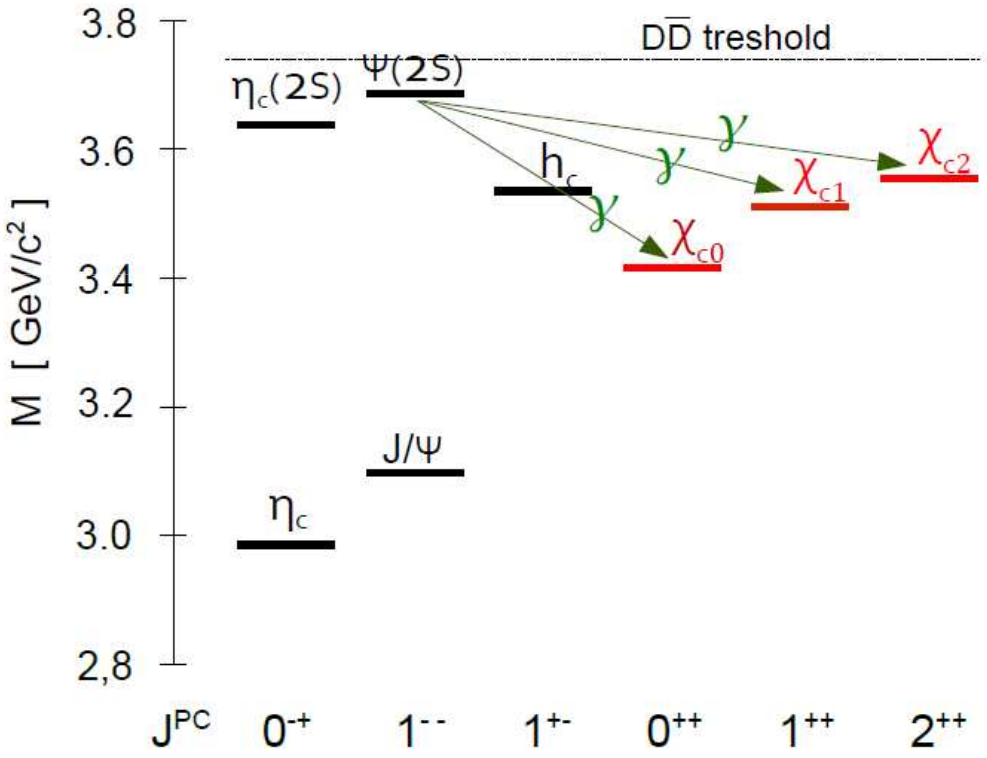




- MDC: $\sigma(p_T)/p_T = 0.5\%$ @ 1GeV
  $dE/dx_{reso} < 6\%$
- TOF: 80 ps (for bhabha, barrel)
- EMC: $\sigma(E)/E = 2.3\% \times \sqrt{E}$
- MUC: 9 layers for barrel,
  8 layers for endcap

The Charmonium System

(Below DDbar threshold)



* Br($\psi' \rightarrow \gamma \chi_{cJ}$) ~ 8% -10%

* ~106M ψ' decays provided a clean and abundant environment to study χ_{cJ} decays

$\chi_{c0,2} \to \pi^0\pi^0, \eta\eta$

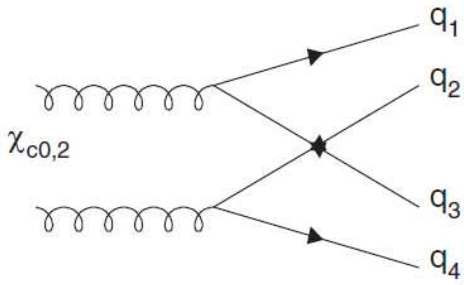
- Exclusive decays of χ_{cJ} provide a good laboratory to test the color octet mechanism in P-wave charmonium decays

G.T. Bodwin et al., Phys Rev. Lett. D51, 1125 (1995)
H.-W. Huang and K.-T. Chao, Phys. Rev. D54, 6850 (1996)
J.Bolz et al., Eur.Phys.J.C2:705-719 (1998)

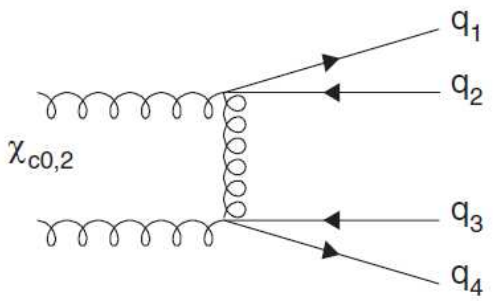
- BRs of $\eta\eta$,$\eta'\eta$,$\eta'\eta'$ determine the relative strength of SOZI and DOZI contributions

Zhao PRD 72, 074001 (2005)

SOZI



DOZI



- Radiative decay of charmonium to $\pi^0\pi^0$, $\eta\eta$ are interesting channels for glueball searches

Branch Fraction Measurement

- $\pi^0, \eta \to \gamma\gamma$
- Branch fraction measurement:

$$Br(\chi_c \to \pi^0\pi^0) = \frac{N_{obs}}{N_{\psi'} \cdot \varepsilon \cdot Br(\psi' \to \gamma\chi_{cJ}) \cdot Br(\pi^0 \to \gamma\gamma) \cdot Br(\pi^0 \to \gamma\gamma)}$$

where:

N_{obs}: observed signal

ε : selection efficiency

$N_{\psi'}$: Number of ψ'

All other branch ratios: from PDG

Selection and Cuts

- Photon candidate: greater than 50 MeV
- Require 5 or 6 photons without charged tracks
- Use the photon pairing giving minimum (raditative photon with E<0.4GeV excluded):

$$\chi_{\pi 0\pi 0/\eta\eta} = (P^2_1+P^2_2)^{1/2}$$

$P_{1,2}$: mass pulls

- Backgrounds with missing final sate particles are suppressed by requiring small p^2_{tr}:

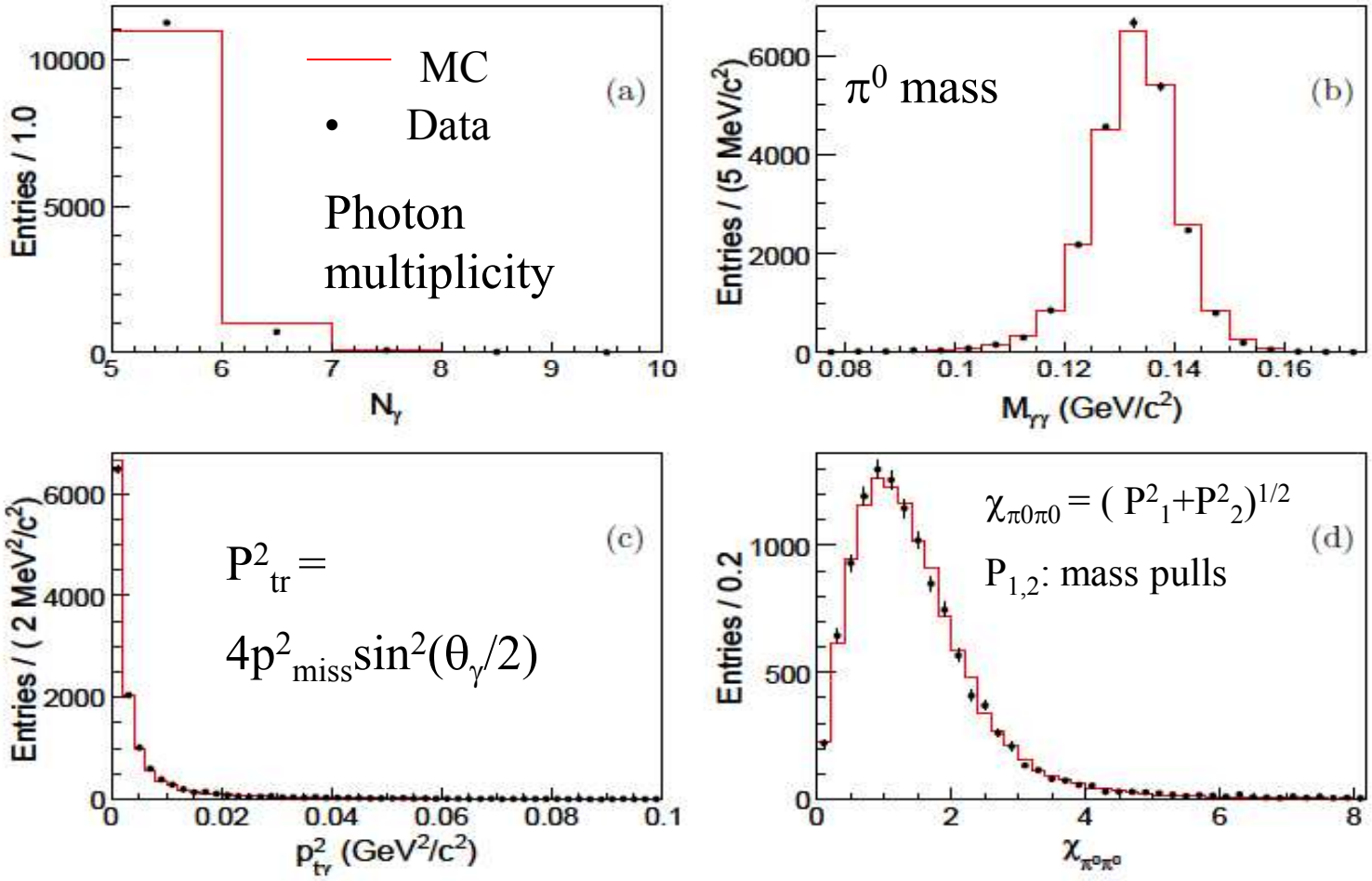
$$p^2_{tr} = 4p^2_{miss}\sin^2(\theta_\gamma/2)$$

p_{miss}: missing momentum opposite to the PP syst.

θ_γ: angle between radiative photon and p_{miss}

Data MC Comparison

$\psi' \rightarrow \gamma \chi_{cJ}$, $\chi_{cJ} \rightarrow \pi^0\pi^0$



Efficiencies and Number of ψ'

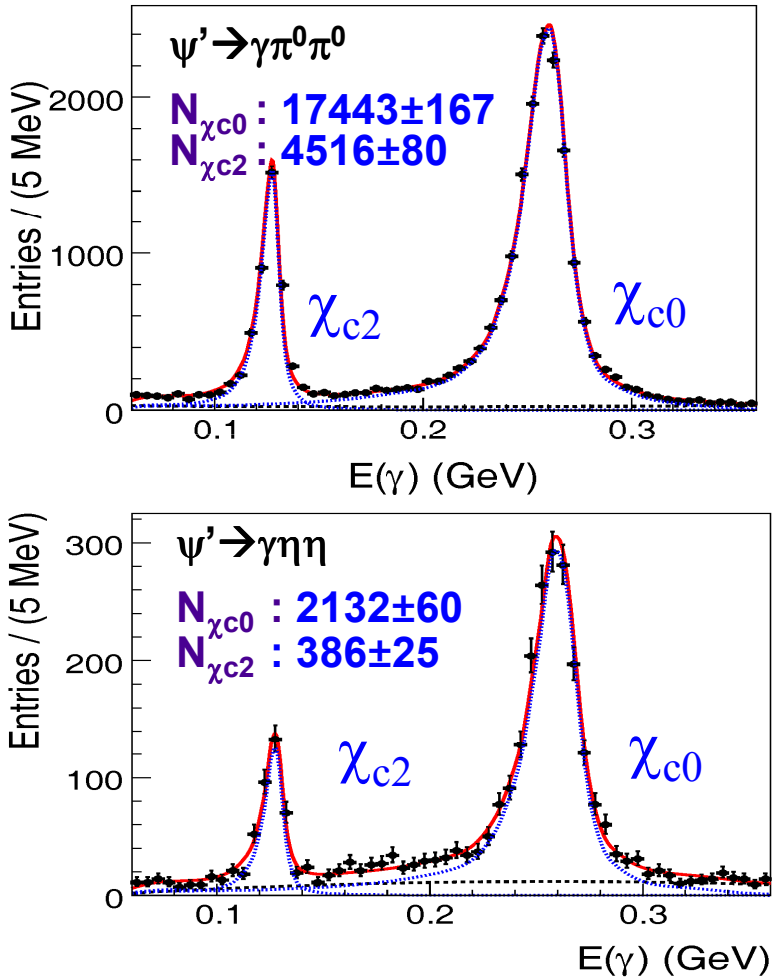
Efficiencies (%) from MC

Mode	χ_{c0}	χ_{c2}
$\pi^0\pi^0$	55.6 ± 0.2	59.8 ± 0.2
$\eta\eta$	40.3 ± 0.2	43.9 ± 0.2

Number of ψ' Events (an independent analysis):

* determined from number of inclusive hadronic ψ' decays
* fitting the distribution of average of the z distance
* result is (1.06 ± 0.04(syst)) x 10^8

Radiative Photon Spectrum Fit



Unbinned maximum likelihood fits:

- Signal shapes: from MC with widths fixed PDG values
- No peaking background by studying inclusive MC and continuum data, described by 2nd-order Chebychev polynomials
- Second paper from BESIII: PRD 81, 052005 (2010)

Branch Fraction Results (10^{-3})

Mode		χ_{c0}	χ_{c2}
$\pi^0\pi^0$	This Work	$3.23 \pm 0.03 \pm 0.23 \pm 0.14$	$0.88 \pm 0.02 \pm 0.06 \pm 0.04$
	CLEOc [2]	$2.94 \pm 0.07 \pm 0.32 \pm 0.15$	$0.68 \pm 0.03 \pm 0.07 \pm 0.04$
	PDG [10]	2.43 ± 0.20	0.71 ± 0.08
$\eta\eta$	This Work	$3.44 \pm 0.10 \pm 0.24 \pm 0.13$	$0.65 \pm 0.04 \pm 0.05 \pm 0.03$
	CLEOc [2]	$3.18 \pm 0.13 \pm 0.31 \pm 0.16$	$0.51 \pm 0.05 \pm 0.05 \pm 0.03$
	PDG [10]	2.4 ± 0.4	< 0.5

BESIII and CLEO-c use different χ production BF

Systematics

TABLE II: Systematic uncertainties expressed in percent.

Mode	$\chi_{c0} \to \pi^0\pi^0$	$\chi_{c2} \to \pi^0\pi^0$	$\chi_{c0} \to \eta\eta$	$\chi_{c2} \to \eta\eta$
photon detection	5	5	5	5
$\pi^0(\eta)$ reconstruction	2	2	2	2
$p^2_{\gamma\gamma}$	0.9	1.2	0.1	0.3
$\chi_{\eta\eta}$	-	-	0.6	2.6
signal shape	1.6	1.2	1.4	1.5
background shape	0.5	0.5	0.2	0.3
fitting range	0.3	0.3	0.8	1.3
trigger	0.1	0.1	0.1	0.1
$N_{\psi'}$	4	4	4	4
Total	7.0	6.9	6.9	7.5

Dominant systs:

1) Photon detection and conversion:
   1% per photon using

   $j/\psi \to \rho\pi$
   $ee \to \gamma\gamma$

2) Number of ψ' decays:

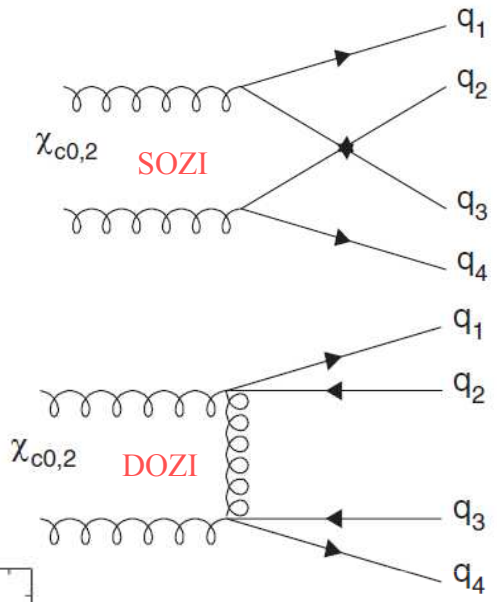
   charged track multiplicity requirement,

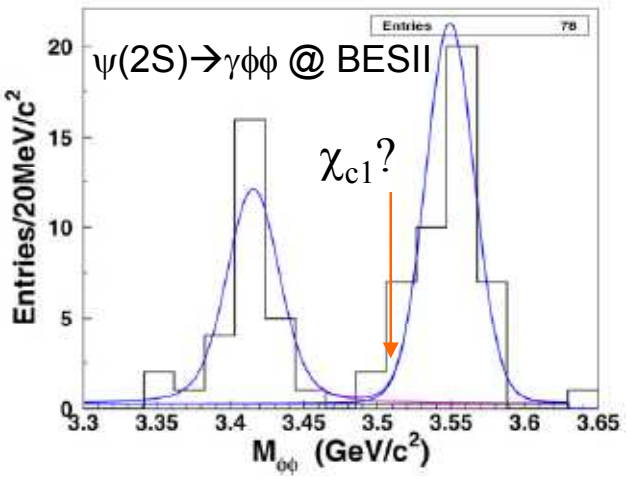
   tracking efficiency

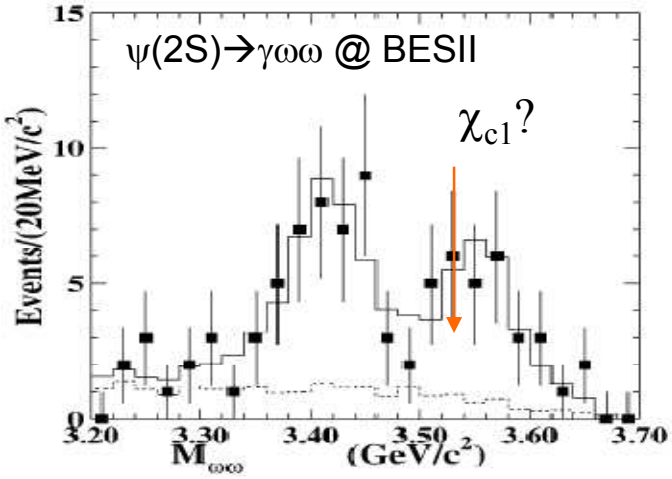
   …

$\chi_{cJ} \rightarrow VV\ (\phi, \omega)$

- $\chi_{cJ} \rightarrow \phi\phi/\omega\omega$, singly OZI suppressed.
- $\chi_{c1} \rightarrow \phi\phi/\omega\omega$, only allowed for L=2 , suppressed?
- $\chi_{cJ} \rightarrow \phi\omega$, doubly OZI suppressed, not measured yet

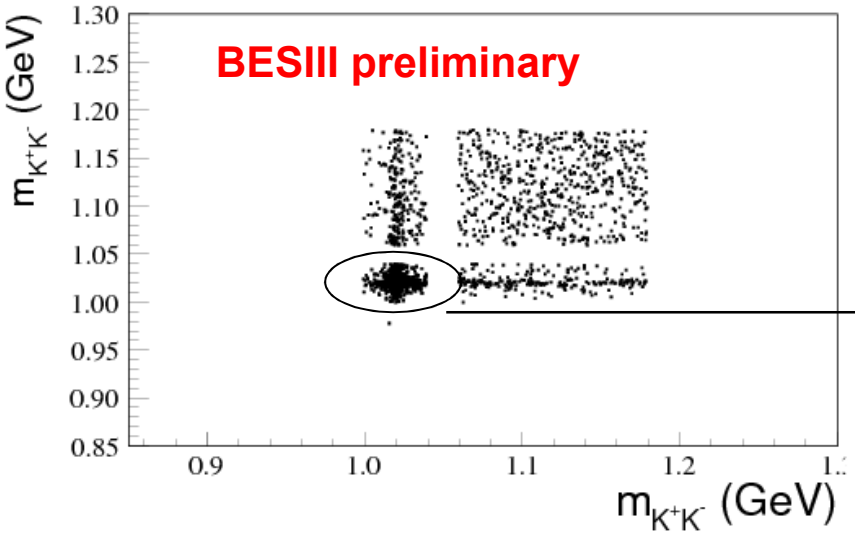


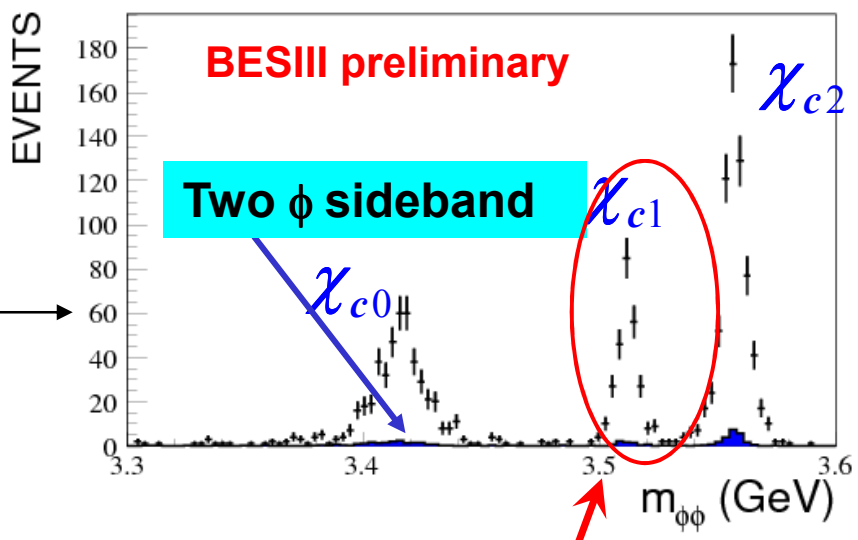




Previous results at BESII: PL B642:192-202, 2006

$\chi_{cJ} \to \phi(KK)\phi(KK)$ Study





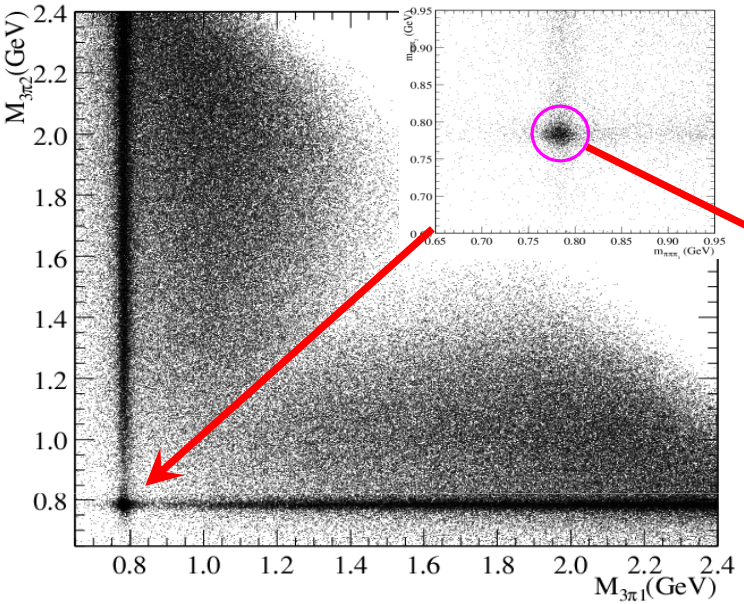
Branching fraction

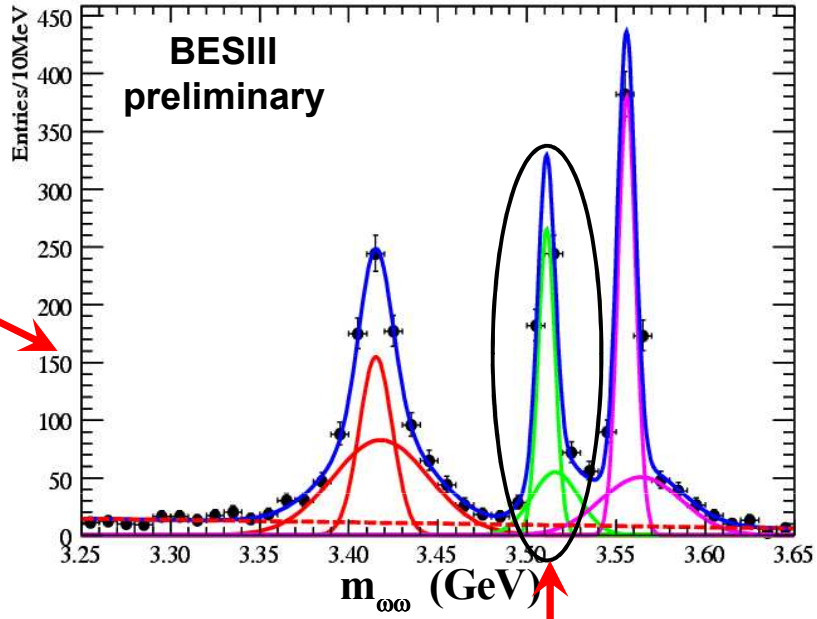
Syst. Error only

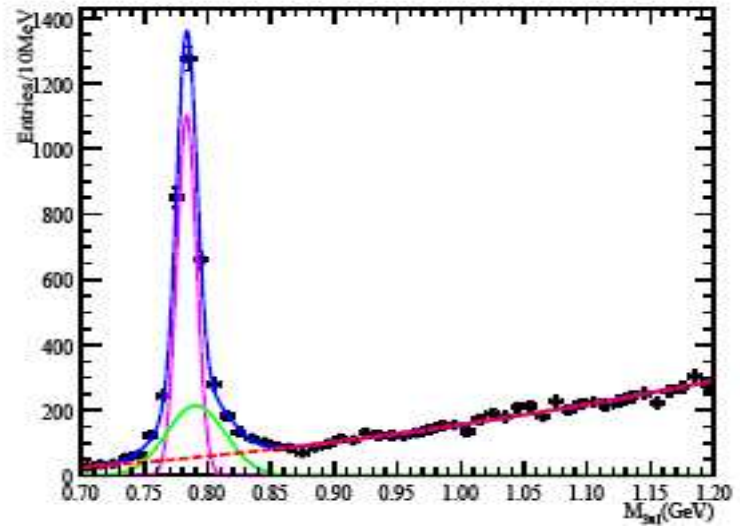
channel	$(\times 10^{-4})$	PDG$(\times 10^{-4})$
$\chi_{c0} \to \phi\phi$	8.0 ± 0.4	9.3 ± 2.0
$\chi_{c1} \to \phi\phi$	4.2 ± 0.3	$- - -$
$\chi_{c2} \to \phi\phi$	11.3 ± 0.4	15.4 ± 3.0

the first measurement of $\chi_{c1} \to \phi\phi$

$\chi_{cJ} \to \omega(\pi\pi\pi^0)\omega(\pi\pi\pi^0)$ Study



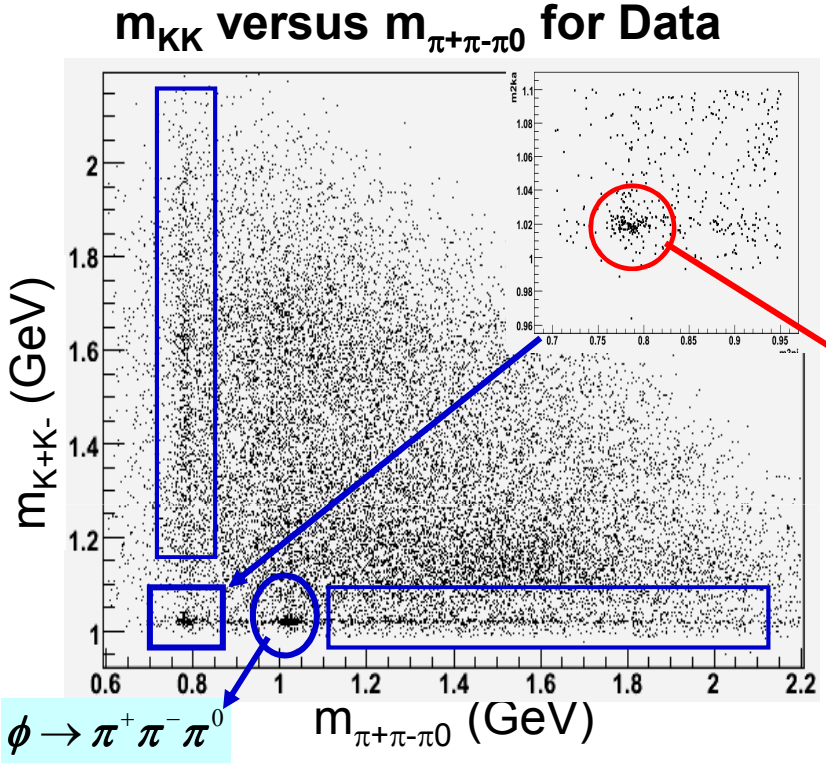




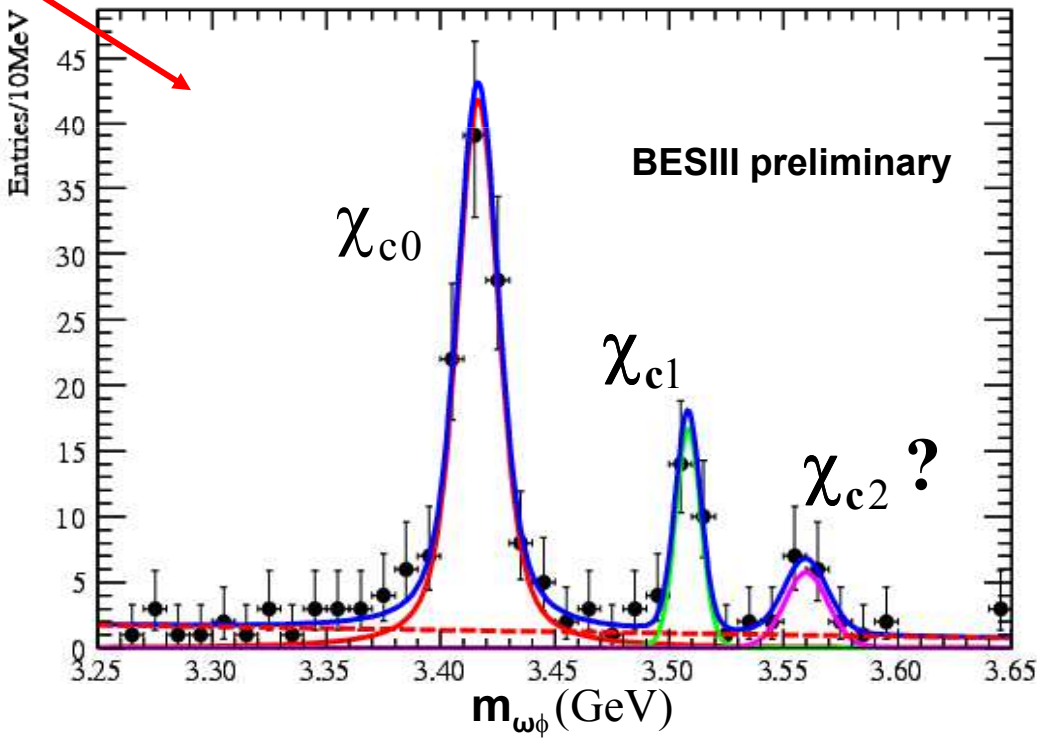
the first measurement of $\chi_{c1} \to \omega\omega$

- $\omega\omega$ signals are clearly observed
- backgrounds and non-resonance contributions are studied with two-ω sidebands and continuum data, very low.

First Observation of $\chi_{cJ} \to \omega\phi$



- $\omega\phi$ signals are clearly observed
- backgrounds and contributions from non-resonances are studied with ω & ϕ sidebands, and continuum data.



- **$\chi_{cJ} \to \phi\omega$ OZI doubly suppressed**
- **Surprise! The doubly suppressed decay is observed**

Studies of $\chi_{cJ} \rightarrow \gamma V(\phi,\rho,\omega)$

•It is an independent and complimentary ccbar-annihilation decay to radiative decays of J/ ψ, and useful in validating theoretical techniques with well know final state hadronic system

•First observations at CLEO-c only reported $\gamma\rho$ and $\gamma\omega$, but no $\gamma\phi$ states

PRL 101 , 151801 (2008)

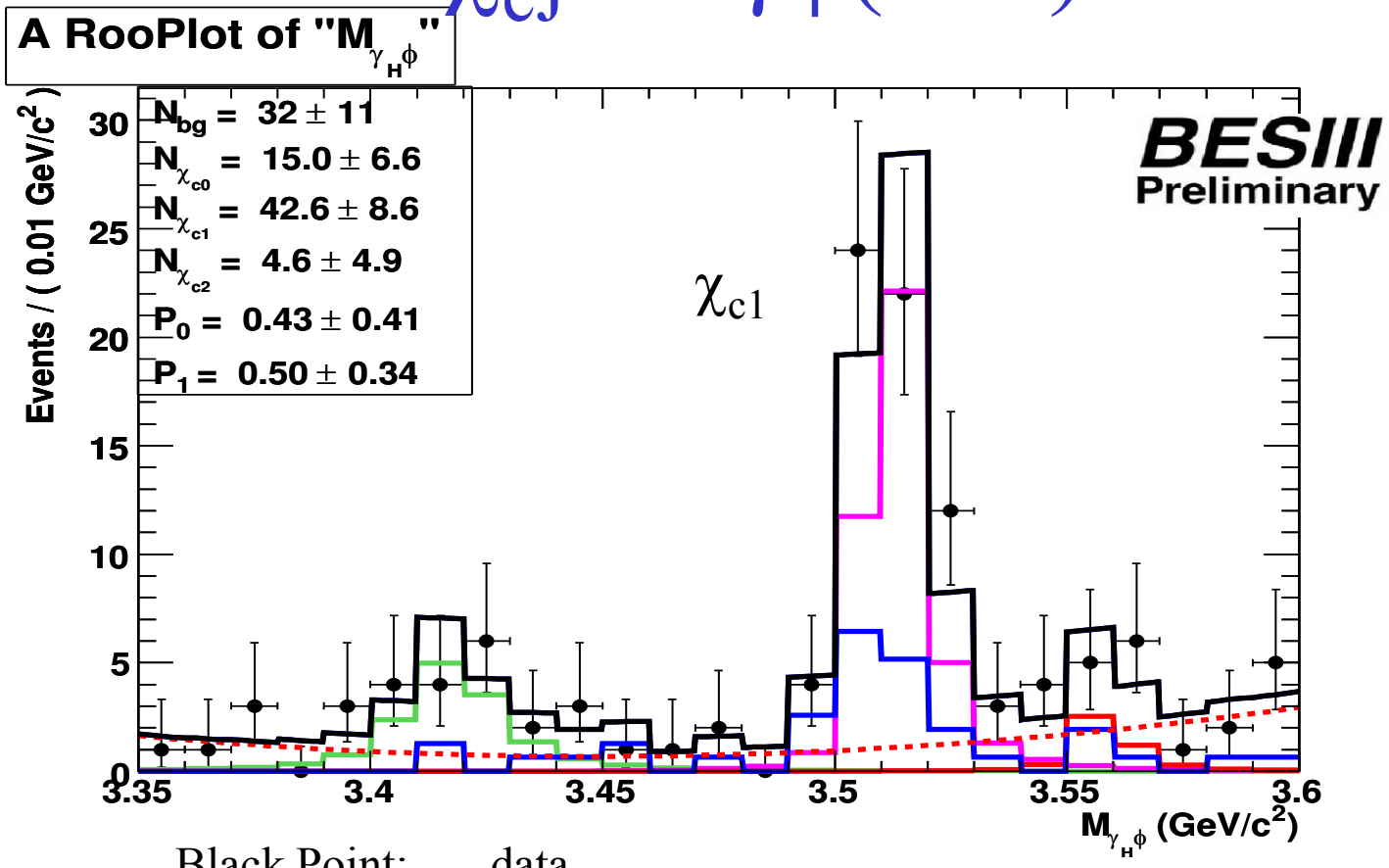
•The CLECO-c results are an order of magnitude higher than previous pQCD calculations by Gao, Zhang and Cao

Chin. Phys. Lett. 23, 2376 (2006)

New theoretical paper including hadronic loop contributions:

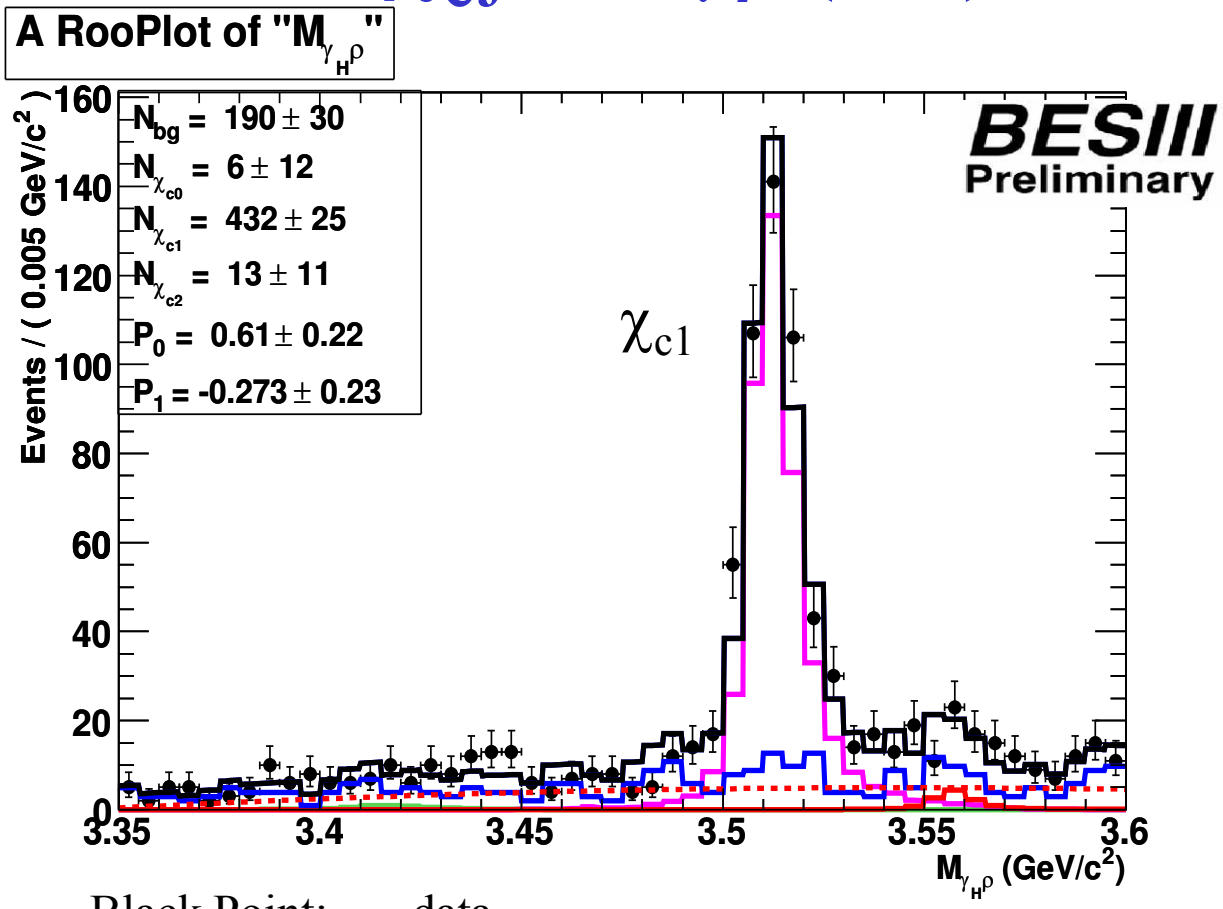
arXiv:1005.0066v2[hep-ph]

$\chi_{cJ} \to \gamma\phi(KK)$



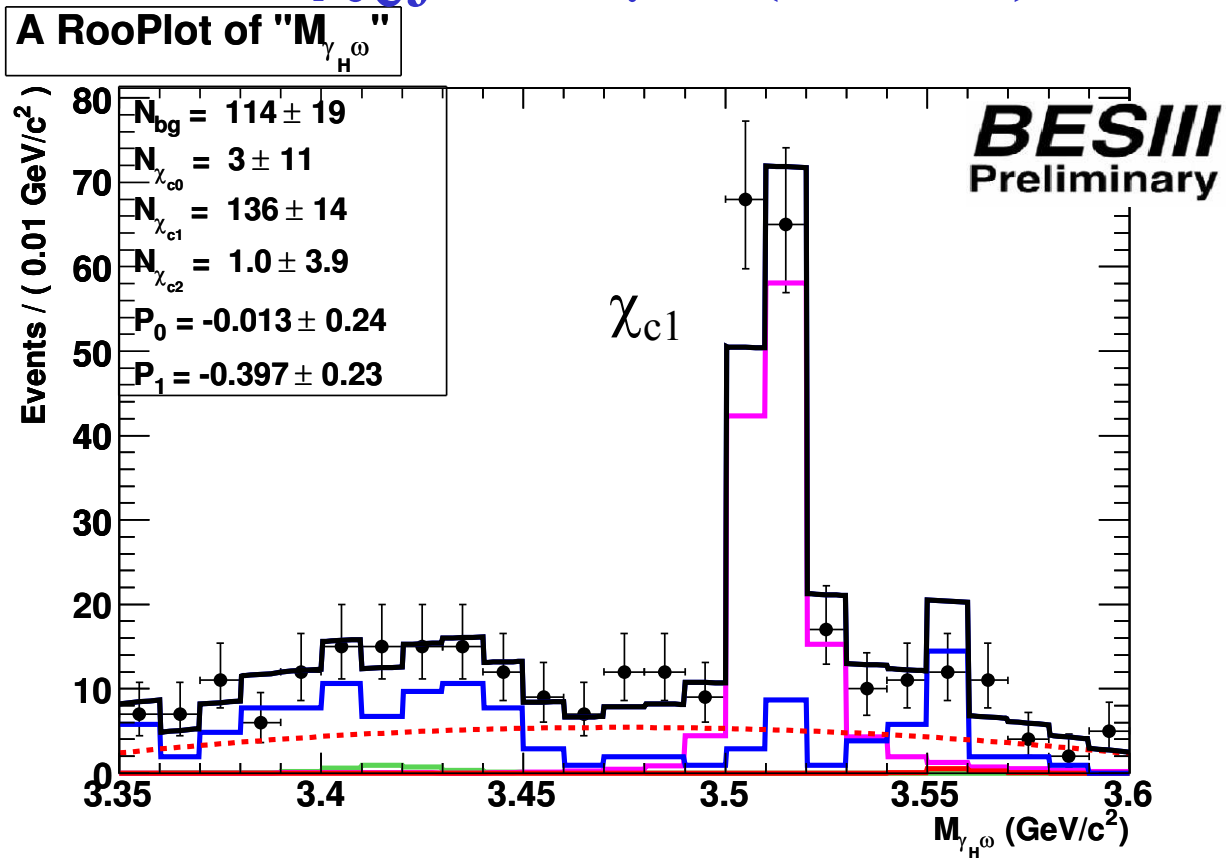
Black Point: data
black histogram: Fit
pink histogram: signal
blue histogram: background from ϕ sideband and continuum
dashed red line: other background

$\chi_{cJ} \to \gamma\rho(\pi\pi)$



Black Point: data
black histogram: Fit
pink histogram: signal
blue histogram: background from ρ sideband and continuum
dashed red line: other background

$\chi_{cJ} \to \gamma\omega(\pi\pi\pi^0)$



Black Point: data
black histogram: Fit
pink histogram: signal
blue histogram: background from ω sideband and continuum
dashed red line: other background

Summary

- BF measurements on $\chi_{cJ} \to \pi^0\pi^0/\eta\eta$ are Published.
- Preliminary results on $\chi_{cJ} \to VV$ including first Observations of $\chi_{c1} \to \phi\phi/\omega\omega$ and $\chi_{cJ} \to \phi\omega$
- Preliminary results of $\chi_{cJ} \to \gamma V$
- More exciting results from BESIII are coming soon

Back Up

MC Generation

– for $\psi(2S) \to \gamma\chi_{cJ}$, E1 transition is assumed

$$\frac{dN}{d\cos\theta_\gamma} \propto (1+\alpha\cos^2\theta_\gamma) \quad \text{with } \alpha = \begin{cases} 1 \text{ for } \chi_{c0} \\ -1/3 \text{ for } \chi_{c1} \\ 1/13 \text{ for } \chi_{c2} \end{cases}$$

– for $\chi_{cJ} \to V_1(\lambda_1)V_2(\lambda_1)$, helicity amplitude $H_{\lambda_1\lambda_1}$ is assumed

P-parity conserved: $H_{-\lambda_1-\lambda_2} = \eta_{\chi_{cJ}}\eta_{V_1}\eta_{V_2}(-1)^{J-J_1-J_2}H_{\lambda_1\lambda_2}$

each component of helicity amplitude has the same value

-- for $\phi(\varepsilon_1) \to K^+(p)K^-(-p)$, amplitude $\propto \varepsilon_1 \bullet p$

-- for $\omega(\varepsilon_1) \to \pi^+(p^+)\pi^-(p^-)\pi^0(p^0)$, amplitude $\propto \varepsilon^{\alpha\beta\mu\nu}\varepsilon_{1\alpha}p^+{}_\beta p^-{}_\mu p^0{}_\nu$